



SPECIFICATION

Drawing No Vers.


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**WA LIGO SITE (LHO) - CORNER STATION ADV. LIGO
VACUUM EQUIPMENT INSTALLATION**

APPROVALS	DATE	REV	DCN NO.	BY	CHECK	DCC	DATE
AUTHOR:	3/4/11	V1	For Installation				
CHECKED:							
APPROVED:							
DCC RELEASE							

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1.0 General Scope

1.1 This specification covers the minimum requirements for the moving and installation of new vacuum equipment required for the WA Advanced LIGO Modification of the LIGO Observatories. This specification covers only the LIGO Hanford, WA (LHO) Corner Station facility.

The Buyer will provide a full time representative to work with the Seller during these activities.

All equipment must be moved / installed while maintaining the strict Cleanliness of the LIGO research facility. Anytime a LIGO vessel is open to atmosphere, it must be protected by a Class 5 cleanroom (provided by LIGO) and Class 5 cleanroom procedures must be used.

All electrical wiring will be removed by others.

1.2 The Buyer will train the Seller personnel in site cleanliness and safety requirements (See Section 8.0 for detailed requirements) prior to the start of the work.

1.3 The California Institute of Technology (Caltech) is the Buyer for these components. The Seller is the successful bidder who is awarded this contract.

The Laser Interferometer Gravitational-Wave Observatory (LIGO) is operated by Caltech and the Massachusetts Institute of Technology (MIT) under a National Science Foundation grant and includes observatories located in the Hanford Reservation ,near Richland, WA (LHO) and in Livingston, LA (LLO).

Viewed from the Corner Station the left equipment arm is the “Y” arm and the right equipment arm is the “X” arm.

1.4 It is the Seller responsibility to follow the requirements of this specification or to propose alternate procedures and specifications to meet the requirements. All alternate approaches must be approved by the Buyer before use.

1.5 The Buyer reserves the right to refuse access to the LIGO facility to any of the Seller’s personnel for failure to adhere to LIGO Site Safety Rules or for refusing to work in a Safe and Clean manner.

1.6 All personnel must read and understand this complete document before proceeding with the work.

1.7 All drawing and specifications referenced herein are part of this specification and are available for viewing via the link in the Statement Of Work – [Cxxxxxxx_v1](#)

2.0 Codes / Standards / Permits

2.1 The following codes and standards (Latest Editions), as applicable, shall be followed for the installation and testing of the equipment:


- ASTM - American Society for Testing Materials
- OSHA - Occupational Safety and Health Act Noise Standard
- Applicable - Local Codes and Standards
- ISO 14644-1 – 1999 Cleanrooms and Associated Controlled Environments
- AISC - American Institute of Steel Construction
- ANSI - American National Standards Institute
- B16.1 Cast Iron Pipe Flanges
- B16.5 Steel Pipe Flanges
- B31.1 Also For Utilities
- B31.3 Chemical Plant and Petroleum Refinery Piping
- B31.9 Building Services Piping
- ASME - American Society of Mechanical Engineers
Section IX, Welding Qualifications -2007
- AWS - American Welding Society

2.2 Permits

Before starting work on this project, it shall be the responsibility of the Seller to make certain that all necessary permits, licenses and approvals are obtained for the work to be performed at the site.

3.0 Safety Requirements

- 3.1 All work executed by the Seller shall comply with Federal OSHA regulations. The Seller is responsible for the Safety of their personnel.
- 3.2 The Seller shall also comply with the Buyer's on-site Construction Safety, Health and Environmental Management program.
- 3.3 The Seller shall be fully responsible for providing first aid equipment and other safety equipment required for their personnel.

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- 3.4 The Seller's foreman shall be responsible for the safe execution of the work at the site. Seller shall conduct weekly safety meetings with their crew and send a representative to all site wide safety meetings.
- 3.5 All piping shall be verified to have no internal pressure before it is cut or the connection is opened. All electrical wiring will be removed by others.
- 3.6 When directed by LIGO, areas where construction work is being done shall be roped off by construction tape, to warn other site personnel.
- 3.7 The Bidders shall submit their Safety Rating as part of their bid submittal and update it quarterly during the contract.
- 3.8 All Riggers shall meet all WA State and OSHA requirements for Riggers and Crane Operators.

4.0 LIGO LHO Site Requirements


- 4.1 The LIGO Observatories are ultra-clean research facilities. The Seller shall make every effort to maintain the normal LIGO cleanliness during installation activities. During equipment de-installation, it is realized that some dusting will occur. The Seller shall minimize the area affected by this dirty work by use of plastic rooms, vacuums, etc.
- 4.2 All installation work must be executed while maintaining the LIGO General Cleanliness Requirements and the requirements of Spec. E1000719. Some work will require clean room garb and practices. Seller's staff shall have new steel toed shoes dedicated to the LIGO work. These shoes should remain on site for the duration of the work so as not to bring contamination from outside sources.
The Seller's personnel must report for work in clean unscented clothing (i.e. no smoke, hydrocarbons, etc.) and be free of after-shave lotions or perfumes. The Buyer will provide all cleanroom clothing and gloves when needed.
- 4.3 Smoking is only allowed outside the LIGO buildings. Personnel shall be Smoke-Free for 10 minutes before re-entering the LIGO facilities.
- 4.4 All parts that touch a vacuum chamber internal surface must be cleaned to strict LIGO requirement (i.e temporary shipping covers). LIGO will clean temporary parts used in the installation for the Seller.

5.0 Detailed Installation Scope

All work shall be accomplished while maintaining the Cleanliness of the LIGO Research Facility.

The Buyer will conduct training for the Seller's personnel relative to site cleanliness requirements and other special site requirements prior to the start of the work.

Critical Instructions are shown in **RED**.

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5.1 General Work Scope

a) To complete the scope of this specification, the Seller will need to remove and re-install large vacuum doors (stainless steel dished heads with o-ring seals – Approx. Wt. 1000 to 1300 Lb.) and move heavy flanged equipment (HAM vessel (Without 60” port covers) Approx. Wt. – 9,000 Lb.). All equipment is bolted together with 7/8 inch fasteners which must be removed and replaced with hand tools. No impact wrenches are allowed. This work requires careful handling of heavy equipment (With critical O-Ring machined sealing surfaces on both ends) using Cranes, Forklifts, Hilman roller, etc.

b) Vessel Movement:

X Arm - The existing Mode Cleaner Spool must be removed. WHAM1 must be removed to make room for the new Mode Cleaner spool (Larger Diameter MC). LHAM1 will be re-installed on the other side of WHAM2. Mode Cleaner Spools WAMCA1 and WAMCB1 can then be installed in between WHAM2 and WHAM3 (See Drawing D1003180)

The existing Mode Cleaner Spool must be removed. WHAM7 must be removed to make room for the new Mode Cleaner spool (Larger Diameter MC). WHAM7 will be re-installed on the other side of WHAM6. Mode Cleaner Spools WAMCA3 and WAMCB3 can then be installed in between WHAM8 and WHAM9 (See Drawing D1003180)


Y Arm – The existing Mode Cleaner Spool must be removed. WHAM6 must be removed to make room for the new Mode Cleaner spool (Larger Diameter MC). WHAM6 will be re-installed on the other side of WHAM5. New Mode Cleaner Spools WAMCA2 and WAMCB2 can then be installed in between LHAM4 and LHAM5 (See Drawing D1003180)

The existing Mode Cleaner Spool must be removed. WHAM12 must be removed to make room for the new Mode Cleaner spool (Larger Diameter MC). WHAM12 will be re-installed on the other side of WHAM11. Mode Cleaner Spools WAMCA4 and WAMCB4 can then be installed in between WHAM10 and WHAM11 (See Drawing D1003180)

c) Much of the installation work takes place under clean room conditions, so the workers must be garbed in Class 5 cleanroom suits when working in Cleanrooms. All equipment ports, when not in a cleanroom shall have clean shipping covers installed on them. When ports are open inside a cleanroom, protective cleanroom cloth (provided by the Buyer) shall be kept over the open ports until the flanges are sealed up.

d) General installation instructions are given below for each item in section 5.2. The seller shall use these general instructions and their site knowledge to prepare their own detailed removal and installation procedures. All Seller procedures must be approved by the Buyer before use.

e) All components have delicate large flanged sealing surfaces. Sealing surface must be protected from damage during all installation operations. A minor scratch in the metal sealing surface (32 RMS finish) will ruin the sealing surface.

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Each time “Protect Flanges” is specified in these procedures, the following shall be executed:

1. Cover each flange surface with Class 5 cleanroom material and secure with SS wire (Particulate protection).
 2. Then cover each flange surface (covering the Class 5 material) with a clean aluminum shipping cover securing with tie-raps (Flange sealing surface protection).
- f) All installation work shall be executed to LIGO Specifications and drawings referenced in section 8 of this specification.
- g) All Viton O-Rings will be provided by the Seller.
- h) Each Building has a Class 5 pressurized air system which the Seller may use.
- i) Any temporary bracing required during installation shall be supplied by the Seller. Any surface that touches LIGO equipments shall be Stainless Steel. (Wood blocking shall not be used)
- j) Any Seller personnel operating the LIGO Building Cranes or Outside Cranes shall be certified to operate that piece of equipment as required by OSHA and the state of WA.
- k) All LIGO building traveling cranes are rated for 10,000 Lb. Max.
- l) All equipment shall be lifted per the component vendor’s instructions
- m) LIGO will remove all vacuum pumps, instrumentation, wiring and wiring trays, Ion pumps and valves prior to the start of this installation work.
- n) The New Vacuum Equipment is being shipped with new clean orings installed on the equipment. All flange sealing surfaces and O-rings must be inspected and re-cleaned during the site installation process as detailed herein.

5.2 Detail Vacuum Equipment Scope

The following work shall be executed by the Seller:

5.2 (A) Detailed Scope – Y Arm Equipment

1) General :

In the Y arm, WHAM6 and WHAM12 must be removed and reinstalled. The New MCA and MCB spools must also be installed in each section.

2) Remove the existing Mode Cleaner Tube (MC) between WHAM5 and WHAM6:

- a) Place a Cleanroom over the MC to WHAM5 60” flanges (Covering WHAM5 completely) and establish Class 5 air quality. Remove all flange bolts and then compress the HAM bellows 1.0 inches. “Protect flanges” on WHAM5 and the MC spool.



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b) While WHAM5 is under the cleanroom, also remove the 60" flange door on the far end of WHAM5. Wrap the 60" flange cover in Class 5 cleanroom material and store outside of the cleanroom for later installation on WHAM6 ("Moved HAM). Clean 60" flange surface per Spec. E0900431. "Protect Flanges" on WHAM5.

c) Move the Cleanroom to the other end of the MC spool covering the MC to WHAM6 60" flanges and establish Class 5 air quality. Remove all flange bolts and then compress the MC bellows 1.5 inches. "Protect Flanges" on WHAM6 and the MC spool. Move the cleanroom to a storage area.

d) Prepare to lift the existing MC spool (Approx. weight: 6500 Lb.) by attaching lifting straps from the MC lifting points to the building crane. Raise the crane to take the slack out of the straps **BUT DO NOT TRY TO LIFT THE MC SPOOL.**

e) Build a plastic room around the MC leg baseplates. Remove the MC spool anchor bolts and chip away enough grout to free up the baseplates using a vacuum to control contamination.

f) Carefully lift the MC spool out of place and store it as directed by LIGO.

g) Place a Cleanroom over WHAM5 covering the 60" flange connection and establish Class 5 air quality. Remove aluminum shipping cover and Class 5 material from the grooved 60" flange (Toward the Vertex). Visually inspect the flange for damage. If the flange is undamaged, install a new Viton o-ring per Spec. E0900431. "Protect Flange" on WHAM5. Move the cleanroom to a storage area.

g) Build a plastic enclosure around the remaining grout pads and remove remaining grout down to the floor height using a vacuum to control contamination. Seal floor in the old grout area as directed by LIGO. (Note: This step can be performed anytime before installing the new MC spools)

3) (3 NOT USED)**4) Move / Install WHAM 6**

a) Place a Cleanroom over WHAM6 covering the 60" flange connection to WHAM4 and all of WHAM6. Establish Class 5 air quality. Remove all flange bolts and then compress the WHAM6 bellows 1.0 inches. "Protect Flanges" on WHAM6 and WHAM4. Remove cleanroom to a storage area.

b) Build a plastic enclosure around WHAM6 and use a vacuum to control contamination. Remove the WHAM6 anchor bolt nuts. Chip away the top 1.0 inch of grout from under the baseplate. The anchor bolt nuts and washers under the HAM baseplate will hold the HAM as the grout is chipped away. Once the baseplate is free from the grout, carefully lift WHAM6 (Approx. weight: 9000 Lb.) with the building crane and relocate it outside of WHAM5.

c) Position WHAM6 with a 12 inch gap in between it and WHAM5 and with the 60" flange vertical centerline on the beamline. Place the cleanroom over WHAM6/WHAM5 (Completely covering WHAM6). Reach thru the cleanroom ceiling with the crane hook and attach to WHAM 6. Establish Class 5 air quality. Install new Viton O-rings and a 60" port cover on the end port of WHAM6 (Previously removed from WHAM5). Install



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new O-Rings on the other end of WHAM6 and clean the 60" WHAM5 flat flange. All O-Rings are to be installed per Spec. E0900431.

d) Lift WHAM6 (While still in the cleanroom), place its Hard Flange (Non-Bellows) 60" flange 102 9/16 inches from the WHAM5 Hard Flange (Non-Bellows) 60" flange and vertically aligned to the beamline. Once the alignment is approved by LIGO, mark all anchor bolt locations. "Protect Flanges" on all open ports. Move the cleanroom to a storage area.

e) Lift WHAM6 and move it aside so the anchor bolt holes can be drilled.

f) A baseplate hole template is required to accurately drill the anchor bolt holes. Anchor bolts shall be installed per LIGO Spec. E1000712 and E1000719. Care shall be used to minimize contamination during anchor bolt hole drilling. The shipping covers should remain on the HAMS during this installation work unless protected by the Class 5 Cleanrooms.

g) After the concrete anchor bolt adhesive has cured, WHAM6 can be carefully lifted onto the anchor bolts using the Building Crane (Using the nuts and washers to hold each HAM baseplate). The WHAM6 bellows should still be compress 1.0 inch creating an Approx. 2 3/8 inch gap between WHAM5 and WHAM6.

h) Place the Cleanroom over the WHAM6 60" flange/WHAM5 60" flange connection and establish Class 5 air quality. Remove shipping covers on the 60" flanges. Clean flange sealing surfaces. Slowly release the tension on the 60" bellows while using the anchor bolt nuts to align flange bolt holes. **The Centerline of the 60" flange on the end of WHAM6 should be (TBD) inches above the floor. TBD to be supplied by LIGO**
Install and tighten all 60" flange bolts. Tighten the anchor bolt nuts in stages per E1000712.

5) Install Mode Cleaner Spools WAMCA2 and WAMCB2 (Between WHAM4 and WHAM5)

a) Once the WHAM6 vessel is De-installed and moved to the end of its Beamline, the new MC Spools can be installed. Move the WAMCA2 and WAMCB2 Spools from the LIGO storage building to the Corner Station and set them on the ground outside the Air-lock door. Clean off the MC Spools outside prior to moving it into the Air-lock room.

b) Move the WAMCA2 and WAMCB2 Spools into the air-lock room one at a time using appropriate rollers and construction equipment. With both doors closed, remove the final plastic shipping protection from the WAMCA2 spool. Clean the outside of the spool prior to opening the interior door of the Corner Station building. The Spool shipping covers (on the 60 inch flanges) remain in place until the WAMCA2 Spool is protected by the Class 5 cleanroom. Replace the bolts on the shipping holes with nylon tie-raps.

c) Roll the MCA2 Spool into the building far enough to get building crane access (WAMCA2 estimated shipping Wt. = 9500 Lb. / WAMCB2 = 9800 Lb.) Close Air-lock inner door. Remove the MSS "Breather System" from the shipping door and cover the hole in the shipping door with cleanroom material

d) Compress the WAMCA2 bellows 1 1/2 inches using the bellows tie-rods (compress each side equally to keep the flanges parallel. Lift the WAMCA2 Spool (following vendor lifting instructions) with the building crane and set it carefully in between the WHAM4 and WHAM5 flanges one inch away from WHAM5. Place WAMCA2 baseplates on top of 1/2 inch CS plates (Which do not block the baseplate holes) to allow alignment



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with WAMCB2. Align the WAMCA2 Spool along the Beamline per Spec E1000716 . The buyer will provide a surveyor to help locate the spool on the beam centerline and will approve bolt hole locations prior to floor drilling.

e) Once the WAMCA2 is aligned, Compress the bellows on WAMCB2 1 ½ inches and lift with the building crane.

Move WAMCB2 into place equally spaced in between WAMCA2 and WHAM4 lining up the WAMCA2 and WAMCB2 60” bolt holes as close as possible. (All spools and HAMS still have 1/8 aluminum 60.5 inch shipping covers in place held by nylon tie-raps). Set the WAMCB2 spool baseplates into 12” long pieces of ½ CS rods to facilitate alignment (across the beamline to allow rolling of the MCB spool to bolt up the MC flanges while inside the cleanroom).

f) Move the HAM Cleanroom over the WAMCA2/WAMCB2 flange connection and establish Class 5 air quality. Once Class 5 is established, slide the WAMCB2 Spool toward WHAM4 and remove the shipping covers on the 84 “ flanges. Clean flange surfaces (Leave the shipping orings in place). Slide the WAMCB2 Spool back toward WAMCA2 and install 20 – bolts (every other hole) to bolt up the 84 “ flange. Finish aligning the WAMCA2 & WAMCB2 spools to the beamline and WHAM4 and WHAM5.

g) Once both WAMCA2 and WAMCB2 are aligned and approved by LIGO, the anchor bolt locations can be marked on the floor. The ends of the MC spools should be 1.0 inches (+/- 0.250 inches) from the HAM flanges.

h) Unbolt the 84 “ flange bolts and slide WAMCB2 toward WHAM4. “Protect Flanges” on the MC spools. Move the HAM Cleanroom with the building crane to a storage location. Carefully lift and move WAMCB2 and then WAMCA2 aside with the building crane to allow drilling of the anchor bolts.

i) While WAMCA2 and WAMCB2 Spools are not needed for alignment, place each 60” and 84” flanges in a cleanroom and establish Class 5 air quality. Unwrap flanges and inspect the sealing surface, clean O-Rings and Flange Faces per E0900431. “Protect Flanges” on all ends and then remove the cleanroom.

j) A baseplate hole template is required to accurately drill the anchor bolt holes. Anchor bolts shall be installed per LIGO Spec. E1000712 and E1000719. Care shall be used to minimize contamination during anchor bolt hole drilling. The shipping covers and Class 5 cleanroom material should remain on the MC spools during this installation work unless protected by the Class 5 Cleanrooms.

k) After the concrete anchor bolt adhesive has cured, the WAMCB2 Spool (With its bellows still compressed 1.5 inches) can be lifted onto the anchor bolts using the Building Crane (Using the nuts and washers to hold each WAMCB2 baseplate). Place the HAM Cleanroom over the WHAM4 60” flange/WAMCB2 60” flange and establish Class 5 air quality. Remove shipping covers on the 60” flanges. Clean sealing surfaces per Spec E0900431. Slowly release the tension on the 60” bellows while using the anchor bolt nuts to align flange bolt holes. Install and tighten all 60” flange bolts. Tighten the anchor bolt nuts in stages per E1000712.

l) Lift WAMCA2 with the building crane and unbolt / remove all legs. Carefully lower WAMCA2 into position between WHAM5 and WAMCB2. Roll the HAM Cleanroom so it extends 4 feet beyond the 84” flange on WAMCB2 and covers the WAMCA2 84” flange. Once the 84” flange of WAMCA2 is under Class 5 air quality, remove the shipping covers. While still supported by the crane, clean the sealing surfaces. Carefully bring the 84” flanges together and install 10 bolts equally spaced.



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m) Re-install the legs on WAMCA2 and use the anchor bolt nuts/washers to support WAMCA2 and to roughly align the 60" flanges. Install and tighten all flange bolts on the 84" flange. Release WAMCA2 from the crane and roll the cleanroom down to cover the 60" flanges on WAMCA2.

n) Once Class 5 air quality is established, remove the shipping covers from the 60" flanges on WHAM5 and WAMCA2, clean flanges. Slowly release the tension on the bellows while using the anchor bolt nuts to align the flanges. Install all flange bolts and tighten.

o) Tighten all WAMCA2 and WAMCB2 anchor bolts per Spec. E1000712.

p) Grout all baseplates per Spec. E1000712 after WAMCA2 and WAMCB2 Spool alignment has been Approved by LIGO.

6. Remove the existing Mode Cleaner Tube (MC) between WHAM11 and WHAM12:

a) Place a Cleanroom over the MC to WHAM11 60" flanges (Covering WHAM11 completely) and establish Class 5 air quality. Remove all flange bolts and then compress the HAM bellows 1.0 inches. "Protect flanges" on WHAM11 and the MC spool.

b) While WHAM11 is under the cleanroom, also remove the 60" flange door on the far end of WHAM11. Wrap the 60" flange cover in Class 5 cleanroom material and store outside of the cleanroom for later installation on WHAM12 ("Moved HAM). Clean 60" flange surface per Spec. E0900431. "Protect Flanges" on WHAM11.

c) Move the Cleanroom to the other end of the MC spool covering the MC to WHAM12 60" flanges and establish Class 5 air quality. Remove all flange bolts and then compress the MC bellows 1.5 inches. "Protect Flanges" on WHAM12 and the MC spool. Move the cleanroom to a storage area.

d) Prepare to lift the existing MC spool (Approx. weight: 6500 Lb.) by attaching lifting straps from the MC lifting points to the building crane. Raise the crane to take the slack out of the straps BUT DO NOT TRY TO LIFT THE MC SPOOL.

e) Build a plastic room around the MC leg baseplates. Remove the MC spool anchor bolts and chip away enough grout to free up the baseplates using a vacuum to control contamination.

f) Carefully lift the MC spool out of place and store it as directed by LIGO.

g) Place a Cleanroom over WHAM11 covering the 60" flange connection and establish Class 5 air quality. Remove aluminum shipping cover and Class 5 material from the grooved 60" flange (Toward the Vertex). Visually inspect the flange for damage. If the flange is undamaged, install a new Viton o-ring per Spec. E0900431. "Protect Flange" on WHAM12. Move the cleanroom to a storage area.

g) Build a plastic enclosure around the remaining grout pads and remove remaining grout down to the floor height using a vacuum to control contamination. Seal floor in the old grout area as directed by LIGO.

(Note: This step can be performed anytime before installing the new MC spools)



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- a) Place a Cleanroom over WHAM12 covering the 60" flange connection to WHAM10 and all of WHAM12. Establish Class 5 air quality. Remove all flange bolts and then compress the WHAM12 bellows 1.0 inches. "Protect Flanges" on WHAM12 and WHAM10. Remove cleanroom to a storage area.
- b) Build a plastic enclosure around WHAM12 and use a vacuum to control contamination. Remove the WHAM12 anchor bolt nuts. Chip away the top 1.0 inch of grout from under the baseplate . The anchor bolt nuts and washers under the HAM baseplate will hold the HAM as the grout is chipped away. Once the baseplate is free from the grout, carefully lift WHAM12 (Approx. weight: 9000 Lb.) with the building crane and relocate it outside of WHAM11.
- c) Position WHAM12 with a 12 inch gap in between it and WHAM11 and with the 60" flange vertical centerline on the beamline. Place the cleanroom over WHAM12/WHAM11 (Completely covering WHAM12). Reach thru the cleanroom ceiling with the crane hook and attach to WHAM 12. Establish Class 5 air quality. Install new Viton O-rings and a 60" port cover on the end port of WHAM12 (Previously removed from WHAM11). Install new O-Rings on the other end of WHAM12 and clean the 60" WHAM11 flat flange. All O-Rings are to be installed per Spec. E0900431.
- d) Lift WHAM12 (While still in the cleanroom), place its Hard Flange (Non-Bellows) 60" flange 102 9/16 inches from the WHAM11 Hard Flange (Non-Bellows) 60" flange and vertically aligned to the beamline. Once the alignment is approved by LIGO, mark all anchor bolt locations. "Protect Flanges" on all open ports. Move the cleanroom to a storage area.
- e) Lift WHAM12 and move it aside so the anchor bolt holes can be drilled.
- f) A baseplate hole template is required to accurately drill the anchor bolt holes. Anchor bolts shall be installed per LIGO Spec. E1000712 and E1000719. Care shall be used to minimize contamination during anchor bolt hole drilling. The shipping covers should remain on the HAMS during this installation work unless protected by the Class 5 Cleanrooms.
- g) After the concrete anchor bolt adhesive has cured, WHAM12 can be carefully lifted onto the anchor bolts using the Building Crane (Using the nuts and washers to hold each HAM baseplate). The WHAM12 bellows should still be compress 1.0 inch creating an Approx. 2 3/8 inch gap between WHAM11 and WHAM12.
- h) Place the Cleanroom over the WHAM12 60" flange/WHAM11 60" flange connection and establish Class 5 air quality. Remove shipping covers on the 60" flanges. Clean flange sealing surfaces. Slowly release the tension on the 60" bellows while using the anchor bolt nuts to align flange bolt holes. **The Centerline of the 60" flange on the end of WHAM12 should be (TBD) inches above the floor. TBD to be supplied by LIGO** Install and tighten all 60" flange bolts. Tighten the anchor bolt nuts in stages per E1000712.

8) Install Mode Cleaner Spools WAMCA4 and WAMCB4 (Between WHAM11 and WHAM12)

- a) Once the WHAM12 vessel is De-installed and moved to the end of it Beamline, the new MC Spools can be installed. Move the WAMCA4 and WAMCB4 Spools from the LIGO storage building to the Corner Station and set them on the ground outside the Air-lock door. Clean off the MC Spools outside prior to moving it into the Air-lock room.



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- b) Move the WAMCA4 and WAMCB4 Spools into the air-lock room one at a time using appropriate rollers and construction equipment. With both doors closed, remove the final plastic shipping protection from the WAMCA4 spool. Clean the outside of the spool prior to opening the interior door of the Corner Station building. The Spool shipping covers (on the 60 inch flanges) remain in place until the WAMCA4 Spool is protected by the Class 5 cleanroom. Replace the bolts on the shipping holes with nylon tie-raps.
- c) Roll the MCA4 Spool into the building far enough to get building crane access (WAMCA4 estimated shipping Wt. = 9500 Lb. / WAMCB4 = 9800 Lb.) Close Air-lock inner door. Remove the MSS "Breather System" from the shipping door and cover the hole in the shipping door with cleanroom material
- d) Compress the WAMCA4 bellows 1 ½ inches using the bellows tie-rods (compress each side equally to keep the flanges parallel. Lift the WAMCA4 Spool (following vendor lifting instructions) with the building crane and set it carefully in between the WHAM11 and WHAM12 flanges one inch away from WHAM11. Place WAMCA4 baseplates on top of ½ inch CS plates (Which do not block the baseplate holes) to allow alignment with WAMCB4. Align the WAMCA4 Spool along the Beamline per Spec E1000716-v1. The buyer will provide a surveyor to help locate the spool on the beam centerline and will approve bolt hole locations prior to floor drilling.
- e) Once the WAMCA4 is aligned, Compress the bellows on WAMCB4 1 ½ inches and lift with the building crane.
Move WAMCB4 into place equally spaced in between WAMCA4 and WHAM10 lining up the WAMCA4 and WAMCB4 60" bolt holes as close as possible. (All spools and HAMS still have 1/8 aluminum 60.5 inch shipping covers in place held by nylon tie-raps). Set the WAMCB4 spool baseplates into 12" long pieces of ½ CS rods to facilitate alignment (across the beamline to allow rolling of the MCB spool to bolt up the MC flanges while inside the cleanroom).
- f) Move the HAM Cleanroom over the WAMCA4/WAMCB4 flange connection and establish Class 5 air quality. Once Class 5 is established, slide the WAMCB4 Spool toward WHAM10 and remove the shipping covers on the 84 " flanges. Clean flange surfaces (Leave the shipping orings in place). Slide the WAMCB4 Spool back toward WAMCA4 and install 20 – bolts (every other hole) to bolt up the 84 " flange. Finish aligning the WAMCA4 & WAMCB4 spools to the beamline and WHAM10 and WHAM11.
- g) Once both WAMCA4 and WAMCB4 are aligned and approved by LIGO, the anchor bolt locations can be marked on the floor. The ends of the MC spools should be 1.0 inches (+/- 0.250 inches) from the HAM flanges.
- h) Unbolt the 84 " flange bolts and slide WAMCB4 toward WHAM10. "Protect Flanges" on the MC spools. Move the HAM Cleanroom with the building crane to a storage location. Carefully lift and move WAMCB4 and then WAMCA4 aside with the building crane to allow drilling of the anchor bolts.
- i) While WAMCA4 and WAMCB4 Spools are not needed for alignment, place each 60" and 84" flanges in a cleanroom and establish Class 5 air quality. Unwrap flanges and inspect the sealing surface, clean O-Rings and Flange Faces per E0900431. "Protect Flanges" on all ends and then remove the cleanroom.
- j) A baseplate hole template is required to accurately drill the anchor bolt holes. Anchor bolts shall be installed per LIGO Spec. E1000712 and E1000719. Care shall be used to minimize contamination during anchor bolt hole drilling. The shipping covers and Class 5 cleanroom material should remain on the MC spools during this installation work unless protected by the Class 5 Cleanrooms.



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k) After the concrete anchor bolt adhesive has cured, the WAMCB4 Spool (With its bellows still compressed 1.5 inches) can be lifted onto the anchor bolts using the Building Crane (Using the nuts and washers to hold each WAMCB4 baseplate). Place the HAM Cleanroom over the WHAM10 60" flange/WAMCB4 60" flange and establish Class 5 air quality. Remove shipping covers on the 60" flanges. Clean sealing surfaces per Spec E0900431. Slowly release the tension on the 60" bellows while using the anchor bolt nuts to align flange bolt holes. Install and tighten all 60" flange bolts. Tighten the anchor bolt nuts in stages per E1000712.

l) Lift WAMCA4 with the building crane and unbolt / remove all legs. Carefully lower WAMCA4 into position between WHAM11 and WAMCB4. Roll the HAM Cleanroom so it extends 4 feet beyond the 84" flange on WAMCB4 and covers the WAMCA4 84" flange. Once the 84" flange of WAMCA4 is under Class 5 air quality, remove the shipping covers. While still supported by the crane, clean the sealing surfaces. Carefully bring the 84" flanges together and install 10 bolts equally spaced.

m) Re-install the legs on WAMCA4 and use the anchor bolt nuts/washers to support WAMCA4 and to roughly align the 60" flanges. Install and tighten all flange bolts on the 84" flange. Release WAMCA4 from the crane and roll the cleanroom down to cover the 60" flanges on WAMCA4.

n) Once Class 5 air quality is established, remove the shipping covers from the 60" flanges on WHAM11 and WAMCA4, clean flanges. Slowly release the tension on the bellows while using the anchor bolt nuts to align the flanges. Install all flange bolts and tighten.

o) Tighten all WAMCA4 and WAMCB4 anchor bolts per Spec. E1000712.

p) Grout all baseplates per Spec. E1000712 after WAMCA4 and WAMCB4 Spool alignment has been Approved by LIGO.

g) Build a plastic enclosure around the remaining grout pads and remove remaining grout down to the floor height using a vacuum to control contamination. Seal floor in the old grout area as directed by LIGO. (Note: This step can be performed anytime before installing the new MC spools)

5.2 (B) Detailed Scope – X Arm Equipment**1) Remove the existing Mode Cleaner Tube (MC) Between WHAM 1 and WHAM2:**

a) Place a Cleanroom over the MC to WHAM2 60" flanges (Covering WHAM2 completely) and establish Class 5 air quality. Remove all flange bolts and then compress the WHAM2 bellows 1.0 inches. "Protect Flanges" on WHAM2 and the MC spool.

b) While WHAM2 is under the cleanroom, also remove the 60" flange door on the far end of WHAM2. Wrap the 60" flange cover in Class 5 cleanroom material and store outside of the cleanroom for later installation on WHAM1 ("Moved HAM). Clean 60" flange surface per Spec. E0900431. "Protect Flange" on WHAM2. Move the cleanroom to a storage area.



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c) Move the Cleanroom to the other end of the MC spool covering the MC to WHAM1 60" flanges and establish Class 5 air quality. Remove all flange bolts and then compress the MC bellows 1.5 inches. "Protect Flanges" on WHAM1 and the MC spool. Move the cleanroom to a storage area.

d) Prepare to lift the existing MC spool (Approx. weight: 6500 Lb.) by attaching lifting straps from the MC lifting points to the building crane. Raise the crane to take the slack out of the straps BUT DO NOT TRY TO LIFT THE MC SPOOL.

e) Build a plastic room around the MC leg baseplates. Remove the MC spool anchor bolts and chip away enough grout to free up the baseplates using a vacuum to control contamination.

f) Carefully lift the MC spool out of place and store it as directed by LIGO.

g) Place a Cleanroom over WHAM2 covering the 60" flange connection and establish Class 5 air quality. Remove aluminum shipping cover and Class 5 material from the grooved 60" flange (Toward the Vertex). Visually inspect the flanges and O-rings for damage. If damaged, install a new Viton O-ring per Spec. E0900431.

h) Build a plastic enclosure around the remaining grout pads and remove remaining grout down to the floor height using a vacuum to control contamination. Seal floor in the old grout area as directed by LIGO. (Note: This step can be performed anytime before installing the new MC spools)

3) Move / Install LHAM 2

a) Place a Cleanroom over WHAM1 covering the 60" flange connection to WHAM3 and all of WHAM1. Establish Class 5 air quality. Remove all flange bolts and then compress the WHAM1 bellows 1.0 inches. "Protect Flanges" on WHAM1 and WHAM3. Remove the cleanroom to a storage area.

b) Build a plastic enclosure around WHAM1 and use a vacuum to control contamination. Remove the WHAM1 anchor bolt nuts. Chip away the top 1.0 inch of grout from under the baseplate . The anchor bolt nuts and washers under the HAM baseplate will hold the HAM as the grout is chipped away. Once the baseplate is free from the grout, carefully lift WHAM1 (Approx. weight: 9000 Lb.) with the building crane and relocate it outside of WHAM2.

c) Position WHAM1 with a 12 inch gap in between it and WHAM2 and with the 60" flange vertical centerline on the beamline. Place the cleanroom over WHAM1/WHAM2 (Completely covering WHAM1). Reach thru the cleanroom ceiling with the crane hook and attach to WHAM 1. Establish Class 5 air quality. Install new Viton O-rings and a 60" port cover on the end port of WHAM1 (Previously removed from WHAM2). Install new O-Rings on the other end of WHAM1 and clean the 60" WHAM2 flat flange. All O-Rings are to be installed per Spec. E0900431.

d) **Lift WHAM1 (While still in the cleanroom) and place it's Hard Flange (Non-Bellows) 60" flange 102 9/16 inches from the WHAM2 Hard Flange (Non-Bellows) 60" flange with its 60" flanges vertical centerline aligned to the beamline.** Once the alignment is approved by LIGO, mark all anchor bolt locations. "Protect Flanges" on all open ports. Move cleanroom to a storage area.

e) Lift WHAM1 and move it aside so the anchor bolt holes can be drilled.



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f) A baseplate hole template is required to accurately drill the anchor bolt holes. Anchor bolts shall be installed per LIGO Spec. E1000712 and E1000719. Care shall be used to minimize contamination during anchor bolt hole drilling. The shipping cover should remain on the HAMS during this installation work unless protected by the Class 5 Cleanrooms.

g) After the concrete anchor bolt adhesive has cured, WHAM1 can be carefully lifted onto the anchor bolts using the Building Crane (Using the nuts and washers to hold each HAM baseplate). The WHAM1 bellows should still be compress 1.0 inch creating an Approx. 2 3/16 inch gap between WHAM1 and WHAM2.

h) Place the Cleanroom over the WHAM1 60" flange/WHAM1 60" flange connection and establish Class 5 air quality. Remove shipping covers on the 60" flanges. Clean flange sealing surfaces. Slowly release the tension on the 60" bellows while using the anchor bolt nuts to align flange bolt holes. **The Centerline of the 60" flange on the end of WHAM1 should be (TBD) inches above the floor. TBD to be supplied by LIGO** Install and tighten all 60" flange bolts. Tighten the anchor bolt nuts in stages per E1000712.

4) Install Mode Cleaner Spools WAMCA1 and WAMCB1 (Between WHAM2 and WHAM3)

a) Once the WHAM1 vessel is De-installed and moved to the end of it Beamline, the new MC Spools can be installed. Move the WAMCA1 and WAMCB1 Spools from the LIGO storage building to the Corner Station and set them on the ground outside the Air-lock door. Clean off the WAMCA1 and WAMCB1 spools outside prior to moving it into the Air-lock room.

b) Move the WAMCA1 and WAMCB1 Spools into the air-lock room one at a time using appropriate rollers and construction equipment . With both doors closed, remove the final plastic shipping protection from the WAMCA1 spool. Clean the outside of the spool prior to opening the interior door of the Corner Station building. The Spool shipping covers (on the 60 inch flanges) remain in place until the WAMCA1 Spool is protected by the Class 5 cleanroom. Replace the bolts on the shipping holes with nylon tie-raps.

c) Roll the WAMCA1 Spool into the building far enough to get building crane access (WAMCA1 estimated shipping Wt. = 9500 Lb. / WAMCB1 = 9800 Lb.) Close Air-lock inner door. Remove the spool "Breather System" from the shipping door and cover the hole in the shipping door with cleanroom material

d) Compress the WAMCA1 bellows 1 ½ inches using the bellows tie-rods (compress each side equally to keep the flanges parallel. Lift the WAMCA1 Spool (following vendor lifting instructions) with the building crane and set it carefully in between the WHAM2 and WHAM3 flanges 1.0 inch away from WHAM2. Place WAMCA1 baseplates on top of ½ inch CS plates (Which do not block the baseplate holes) to allow alignment with WAMCB1. Align the WAMCA1 Spool along the Beamline per Spec E1000716 . The buyer will provide a surveyor to help locate the spool on the beam centerline and will approve bolt hole locations prior to floor drilling.

e) Once the WAMCA1 is aligned, Compress the bellows on WAMCB1 1 ½ inches and lift with the building crane. Move WAMCB1 into place equally spaced in between WAMCA1 and WHAM3 lining up the WAMCA1 and WAMCB1 60" flange bolt holes as close as possible. (All spools and HAMS still have 1/8 aluminum 60.5 inch shipping covers in place held by nylon tie-raps). Set the WAMCB1 spool baseplates on to 12" long pieces of ½ CS rods to facilitate alignment (across the beamline to allow rolling of the WAMCB1 spool to bolt up the MC flanges while inside the cleanroom).



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f) Move the HAM Cleanroom over the WAMCA1/WAMCB1 flange connection and establish Class 5 air quality. Once Class 5 is established, slide the WAMCB1 Spool toward LHAM3 and remove the shipping covers on the 84 " flanges. Clean flange surfaces (Leaving the shipping orings in place) on the 84 inch flanges. Slide the WAMCB1 Spool back toward WAMCA1 and install 20 – bolts (every other hole) to bolt up the 84 " flange. Finish aligning the WAMCA1 & WAMCB1 spools.

g) Once both WAMCA1 and WAMCB1 are aligned and approved by LIGO, the anchor bolt locations can be marked on the floor. The ends of the WAMC1 spools should be 1.0 inches (+/- 0.250 inches) from the HAM flanges.

h) Unbolt the 84 " flange bolts and slide WAMCB1 toward WHAM3. "Protect Flanges" on the MC spools. Move the HAM Cleanroom with the building crane to a storage location. Carefully lift and move WAMCB1 and then WAMCA1 aside with the building crane to allow drilling of the anchor bolts.

i) While WAMCA1 and WAMCB1 Spools are not needed for alignment, place each 60" and 84" flanges in a cleanroom and establish Class 5 air quality. Unwrap flanges and inspect the sealing surface, inspect and clean O-Rings (Replace O-rings if damaged) and Flange Faces per E0900431. "Protect Flanges" on all ends and then remove the cleanroom.

j) A baseplate hole template is required to accurately drill the anchor bolt holes. Anchor bolts shall be installed per LIGO Spec. E1000712 and E1000719. Care shall be used to minimize contamination during anchor bolt hole drilling. The shipping covers and Class 5 cleanroom material should remain on the MC spools during this installation work unless protected by the Class 5 Cleanrooms.

k) After the concrete anchor bolt adhesive has cured, the WAMCB1 Spool (With its bellows still compressed 1.5 inches) can be lifted onto the anchor bolts using the Building Crane (Using the nuts and washers to hold each MCB baseplate). Place the HAM Cleanroom over the WHAM3 60" flange/WAMCB1 60" flange and establish Class 5 air quality. Remove shipping covers on the 60" flanges. Clean sealing surfaces per Spec E0900431. Slowly release the tension on the 60" bellows while using the anchor bolt nuts to align flange bolt holes. Install and tighten all 60" flange bolts. Tighten the anchor bolt nuts in stages per E1000712.

l) Lift WAMCA1 with the building crane and unbolt / remove all legs. Carefully lower WAMCA1 into position between WHAM1 and WAMCB1. Roll the HAM Cleanroom so it extends 4 feet beyond the 84" flange on WAMCB1 and covers the WAMCA1 84" flange. Once the 84" flange of WAMCA1 is under Class 5 air quality, remove the shipping covers. While still supported by the crane, clean the sealing surfaces. Carefully bring the 84" flanges together and install 10 bolts equally spaced.

m) Re-install the legs on WAMCA1 and use the anchor bolt nuts/washers to support WAMCA1 and to roughly align the 60 " flanges. Install and tighten all flange bolts on the 84" flange. Release WAMCA1 from the crane and roll the cleanroom down to cover the 60" flanges on WAMCA1 / WHAM2.

n) Once Class 5 air quality is established, remove the shipping covers from the 60" flanges on WHAM2 and WAMCA1, clean flanges. Slowly release the tension on WHAM2 bellows while using the anchor bolt nuts to align the flanges. Install all flange bolts and tighten.

o) Tighten all WAMCA1 and WAMCB1 anchor bolts per Spec. E1000712.



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p) Grout all baseplates per Spec. E1000712 after WAMCA1 and WAMCB1 Spool alignment has been Approved by LIGO.

5) Remove the existing Mode Cleaner Tube (MC) Between WHAM 7 and WHAM8:

a) Place a Cleanroom over the MC to WHAM8 60" flanges (Covering WHAM8 completely) and establish Class 5 air quality. Remove all flange bolts and then compress the WHAM8 bellows 1.0 inches. "Protect Flanges" on WHAM8 and the MC spool.

b) While WHAM8 is under the cleanroom, also remove the 60" flange door on the far end of WHAM8. Wrap the 60" flange cover in Class 5 cleanroom material and store outside of the cleanroom for later installation on WHAM7 ("Moved HAM). Clean 60" flange surface per Spec. E0900431. "Protect Flange" on WHAM8. Move the cleanroom to a storage area.

c) Move the Cleanroom to the other end of the MC spool covering the MC to WHAM7 60" flanges and establish Class 5 air quality. Remove all flange bolts and then compress the MC bellows 1.5 inches. "Protect Flanges" on WHAM7 and the MC spool. Move the cleanroom to a storage area.

d) Prepare to lift the existing MC spool (Approx. weight: 6500 Lb.) by attaching lifting straps from the MC lifting points to the building crane. Raise the crane to take the slack out of the straps BUT DO NOT TRY TO LIFT THE MC SPOOL.

e) Build a plastic room around the MC leg baseplates. Remove the MC spool anchor bolts and chip away enough grout to free up the baseplates using a vacuum to control contamination.

f) Carefully lift the MC spool out of place and store it as directed by LIGO.

g) Place a Cleanroom over WHAM8 covering the 60" flange connection and establish Class 5 air quality. Remove aluminum shipping cover and Class 5 material from the grooved 60" flange (Toward the Vertex). Visually inspect the flanges and O-rings for damage. If damaged, install a new Viton O-ring per Spec. E0900431.

h) Build a plastic enclosure around the remaining grout pads and remove remaining grout down to the floor height using a vacuum to control contamination. Seal floor in the old grout area as directed by LIGO. (Note: This step can be performed anytime before installing the new MC spools)

6) Move / Install LHAM 7

a) Place a Cleanroom over WHAM7 covering the 60" flange connection to WHAM9 and all of WHAM7. Establish Class 5 air quality. Remove all flange bolts and then compress the WHAM7 bellows 1.0 inches. "Protect Flanges" on WHAM7 and WHAM9. Remove the cleanroom to a storage area.

b) Build a plastic enclosure around WHAM7 and use a vacuum to control contamination. Remove the WHAM7 anchor bolt nuts. Chip away the top 1.0 inch of grout from under the baseplate .



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The anchor bolt nuts and washers under the HAM baseplate will hold the HAM as the grout is chipped away. Once the baseplate is free from the grout, carefully lift WHAM7 (Approx. weight: 9000 Lb.) with the building crane and relocate it outside of WHAM8.

c) Position WHAM7 with a 12 inch gap in between it and WHAM8 and with the 60" flange vertical centerline on the beamline. Place the cleanroom over WHAM7/WHAM9 (Completely covering WHAM7). Reach thru the cleanroom ceiling with the crane hook and attach to WHAM 7. Establish Class 5 air quality. Install new Viton O-rings and a 60" port cover on the end port of WHAM7 (Previously removed from WHAM8). Install new O-Rings on the other end of WHAM7 and clean the 60" WHAM8 flat flange. All O-Rings are to be installed per Spec. E0900431.

d) Lift WHAM7 (While still in the cleanroom) and place it's Hard Flange (Non-Bellows) 60" flange 102 9/16 inches from the WHAM8 Hard Flange (Non-Bellows) 60" flange with its 60" flanges vertical centerline aligned to the beamline. Once the alignment is approved by LIGO, mark all anchor bolt locations. "Protect Flanges" on all open ports. Move cleanroom to a storage area.

e) Lift WHAM7 and move it aside so the anchor bolt holes can be drilled.

f) A baseplate hole template is required to accurately drill the anchor bolt holes. Anchor bolts shall be installed per LIGO Spec. E1000712 and E1000719. Care shall be used to minimize contamination during anchor bolt hole drilling. The shipping cover should remain on the HAMS during this installation work unless protected by the Class 5 Cleanrooms.

g) After the concrete anchor bolt adhesive has cured, WHAM7 can be carefully lifted onto the anchor bolts using the Building Crane (Using the nuts and washers to hold each HAM baseplate). The WHAM7 bellows should still be compress 1.0 inch creating an Approx. 2 3/16 inch gap between WHAM7 and WHAM8.

h) Place the Cleanroom over the WHAM7 60" flange/WHAM7 60" flange connection and establish Class 5 air quality. Remove shipping covers on the 60" flanges. Clean flange sealing surfaces. Slowly release the tension on the 60" bellows while using the anchor bolt nuts to align flange bolt holes. **The Centerline of the 60" flange on the end of WHAM7 should be (TBD) inches above the floor. TBD to be supplied by LIGO** Install and tighten all 60" flange bolts. Tighten the anchor bolt nuts in stages per E1000712.

7) Install Mode Cleaner Spools WAMCA3 and WAMCB3 (Between WHAM8 and WHAM9)

a) Once the WHAM7 vessel is De-installed and moved to the end of it Beamline, the new MC Spools can be installed. Move the WAMCA3 and WAMCB3 Spools from the LIGO storage building to the Corner Station and set them on the ground outside the Air-lock door. Clean off the WAMCA3 and WAMCB3 spools outside prior to moving it into the Air-lock room.

b) Move the WAMCA3 and WAMCB3 Spools into the air-lock room one at a time using appropriate rollers and construction equipment . With both doors closed, remove the final plastic shipping protection from the WAMCA3 spool. Clean the outside of the spool prior to opening the interior door of the Corner Station building. The Spool shipping covers (on the 60 inch flanges) remain in place until the WAMCA3 Spool is protected by the Class 5 cleanroom. Replace the bolts on the shipping holes with nylon tie-raps.

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c) Roll the WAMCA3 Spool into the building far enough to get building crane access (WAMCA3 estimated shipping Wt. = 9500 Lb. / WAMCB3 = 9800 Lb.) Close Air-lock inner door. Remove the MSS "Breather System" from the shipping door and cover the hole in the shipping door with cleanroom material

d) Compress the WAMCA3 bellows 1 ½ inches using the bellows tie-rods (compress each side equally to keep the flanges parallel. Lift the WAMCA3 Spool (following vendor lifting instructions) with the building crane and set it carefully in between the WHAM8 and WHAM9 flanges 1.0 inch away from WHAM9. Place WAMCA3 baseplates on top of ½ inch CS plates (Which do not block the baseplate holes) to allow alignment with WAMCB3. Align the WAMCA3 Spool along the Beamline per Spec E1000716-v1 . The buyer will provide a surveyor to help locate the spool on the beam centerline and will approve bolt hole locations prior to floor drilling.

e) Once the WAMCA3 is aligned, Compress the bellows on WAMCB3 1 ½ inches and lift with the building crane. Move WAMCB3 into place equally spaced in between WAMCA3 and WHAM9 lining up the WAMCA3 and WAMCB3 60" flange bolt holes as close as possible. (All spools and HAMS still have 1/8 aluminum 60.5 inch shipping covers in place held by nylon tie-raps). Set the WAMCB3 spool baseplates on to 12" long pieces of ½ CS rods to facilitate alignment (across the beamline to allow rolling of the WAMCB3 spool to bolt up the MC flanges while inside the cleanroom).

f) Move the HAM Cleanroom over the WAMCA3/WAMCB3 flange connection and establish Class 5 air quality. Once Class 5 is established, slide the WAMCB3 Spool toward LHAM9 and remove the shipping covers on the 84 " flanges. Clean flange surfaces (Leaving the shipping orings in place) on the 84 inch flanges. Slide the WAMCB3 Spool back toward WAMCA3 and install 20 – bolts (every other hole) to bolt up the 84 " flange. Finish aligning the WAMCA3 & WAMCB3 spools.


g) Once both WAMCA3 and WAMCB3 are aligned and approved by LIGO, the anchor bolt locations can be marked on the floor. The ends of the WAMC3 spools should be 1.0 inches (+/- 0.250 inches) from the HAM flanges.

h) Unbolt the 84 " flange bolts and slide WAMCB3 toward WHAM9. "Protect Flanges" on the MC spools. Move the HAM Cleanroom with the building crane to a storage location. Carefully lift and move WAMCB3 and then WAMCA3 aside with the building crane to allow drilling of the anchor bolts.

i) While WAMCA3 and WAMCB3 Spools are not needed for alignment, place each 60" and 84" flanges in a cleanroom and establish Class 5 air quality. Unwrap flanges and inspect the sealing surface, inspect and clean O-Rings (Replace O-rings if damaged) and Flange Faces per E0900431. "Protect Flanges" on all ends and then remove the cleanroom.

j) A baseplate hole template is required to accurately drill the anchor bolt holes. Anchor bolts shall be installed per LIGO Spec. E1000712 and E1000719. Care shall be used to minimize contamination during anchor bolt hole drilling. The shipping covers and Class 5 cleanroom material should remain on the MC spools during this installation work unless protected by the Class 5 Cleanrooms.

k) After the concrete anchor bolt adhesive has cured, the WAMCB3 Spool (With its bellows still compressed 1.5 inches) can be lifted onto the anchor bolts using the Building Crane (Using the nuts and washers to hold each MCB baseplate). Place the HAM Cleanroom over the WHAM9 60" flange/WAMCB3 60" flange and establish Class 5 air quality. Remove shipping covers on the 60" flanges. Clean sealing surfaces per Spec

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E0900431. Slowly release the tension on the 60” bellows while using the anchor bolt nuts to align flange bolt holes. Install and tighten all 60” flange bolts. Tighten the anchor bolt nuts in stages per E1000712.

l) Lift WAMCA3 with the building crane and unbolt / remove all legs. Carefully lower WAMCA3 into position between WHAM7 and WAMCB3. Roll the HAM Cleanroom so it extends 4 feet beyond the 84” flange on WAMCB3 and covers the WAMCA3 84” flange. Once the 84” flange of WAMCA3 is under Class 5 air quality, remove the shipping covers. While still supported by the crane, clean the sealing surfaces. Carefully bring the 84” flanges together and install 10 bolts equally spaced.

m) Re-install the legs on WAMCA3 and use the anchor bolt nuts/washers to support WAMCA3 and to roughly align the 60 “ flanges. Install and tighten all flange bolts on the 84” flange. Release WAMCA3 from the crane and roll the cleanroom down to cover the 60” flanges on WAMCA3 / WHAM8.

n) Once Class 5 air quality is established, remove the shipping covers from the 60” flanges on WHAM8 and WAMCA3, clean flanges. Slowly release the tension on WHAM8 bellows while using the anchor bolt nuts to align the flanges. Install all flange bolts and tighten.

o) Tighten all WAMCA3 and WAMCB3 anchor bolts per Spec. E1000712.

p) Grout all baseplates per Spec. E1000712 after WAMCA3 and WAMCB3 Spool alignment has been Approved by LIGO.

5.2 (C) Detailed Scope – Piping Modifications

1. Because of the addition of the New (Larger) Mode Cleaner Spools WAMCA2 and WAMCB2, the Clean Air, Vacuum Headers and utility piping originating from the Mechanical Room into the Vacuum Equipment Area (as the piping exits the pipe rack and rolls under the vacuum vessel beamline) needs to be modified to accommodate the Advanced LIGO equipment arrangement. (See Dwg. D961174 and D961176)

The P&ID and the piping drawings detail piping line numbers. The Piping Design Specification E1000713 details requirements for each line number.

2. All Piping modification shall conform to documents referenced in sections 2.0 “Codes and Standards” and 8.0 “Attachments” of this specification.

3. Working with LIGO representatives, the Seller shall redesign, fabricate and install Vacuum and utility piping for this area. The Seller shall prepare Piping arrangement drawing detailing the New piping design. LIGO must approve all designs prior to material procurement and fabrication.

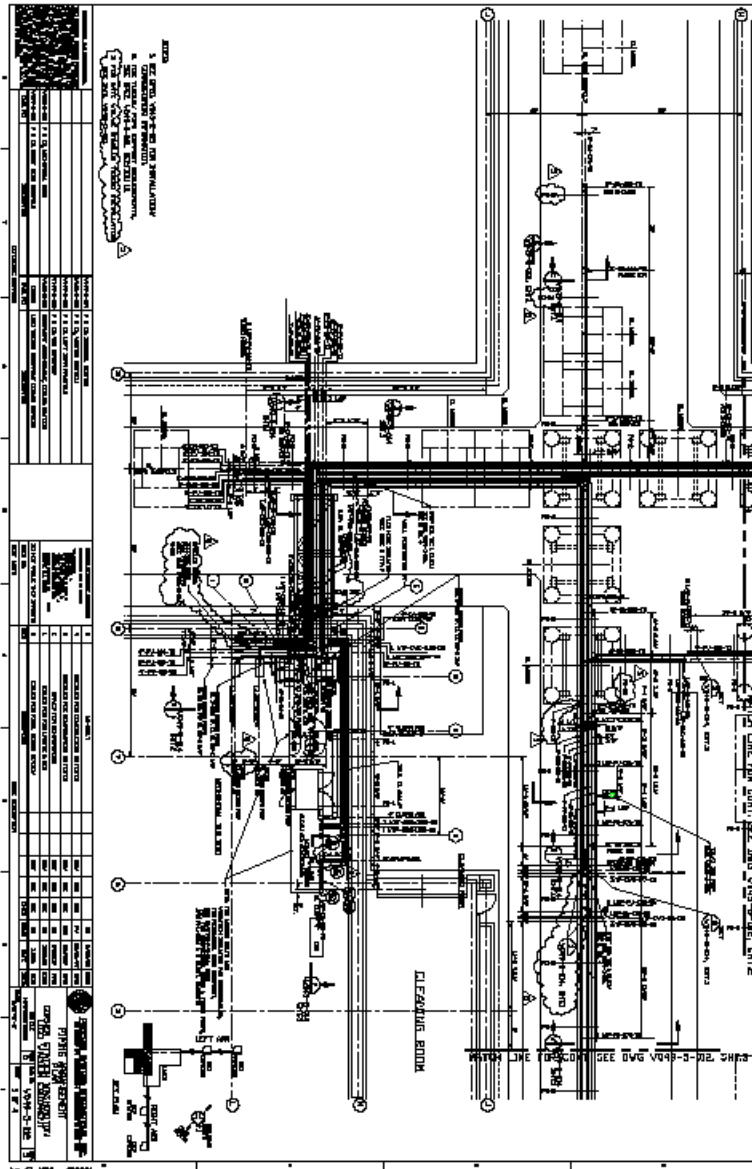


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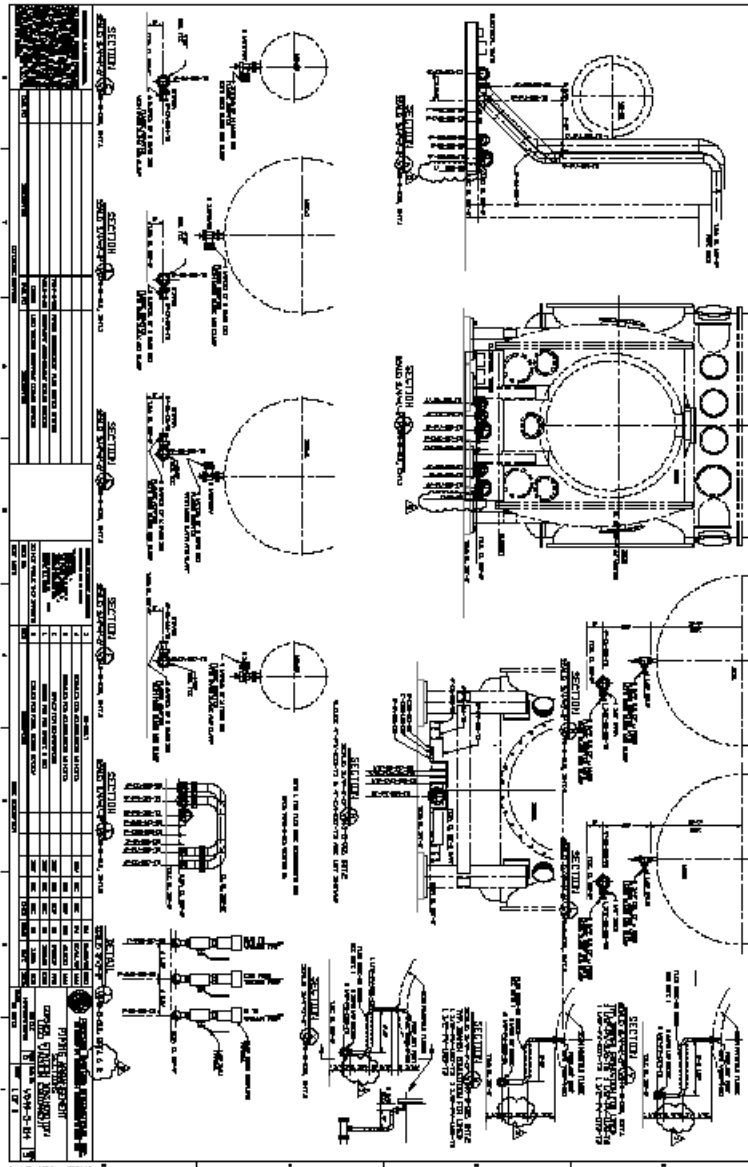
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4. The Contractor shall supply all necessary welding procedures. Welding procedures shall be submitted by the Seller to the Buyer for acceptance prior to commencement of welding. The Contractor shall qualify welding procedures and welders in accordance with ASME Boiler and Pressure Vessel Code, Section IX, latest edition. All welding must be done outside the laser/vacuum equipment areas in a clean shop environment.

The Contractor shall protect piping systems from the entrance of moisture and foreign materials and protect all knife edges of “conflat” flanges. (See E1000718 for additional requirements).

5. Pipe Testing

Required tests shall be conducted in the presence of the Buyer's representative. The Buyer's representative shall be notified at least 4 hours prior to the performance of a test. The Buyer shall determine if test results are acceptable. Costs for repairing failed items and re-testing shall be by the Contractor.

The following tests shall be conducted:


- a. Cooling Water - Pressure decay at 1.1 design pressure.
- b. Instrument Air - Pressure decay at 1.1 design pressure
- c. Class 100 Air - Press decay at 1.1 design pressure
- d. Vacuum Piping – Helium Leak Testing

The Seller shall provide written documentation for all testing (Test sheet, Procedures, etc.)

6. Piping Insulation

Insulation shall be installed on equipment and piping as indicated on the Piping and Instrumentation Diagrams (P&ID's). The Contractor shall provide all insulation materials. Insulation is to be installed by the Seller per E1000717.

Insulation for piping inside buildings shall be installed on piping spools prior to installation.

	LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY SPECIFICATION	E1000708 -V1
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WA LIGO SITE (LHO) - CORNER STATION ADV. LIGO VACUUM EQUIPMENT INSTALLATION		

6.0 Equipment and Materials

6.1 Equipment and Materials Supplied By the Buyer for use by the Seller:

- a) 5 Ton Building Cranes in each building and associated new lifting straps (for use inside the LIGO Buildings only).
- b) “Baked” Viton O-Rings for each sealing flange
- c) Clean small tools for removing nuts and bolts on equipment flanges (For use inside LIGO buildings only)
- d) Cleanroom clothes and Cleanroom material for protecting flange sealing surfaces
- e) All new vacuum equipment spools including nuts and bolts.

6.2 Equipment and Materials Supplied By the Seller:

The Seller must provide all additional materials needed to accomplish the scope of this specification that is not provided by the Buyer. All installation materials purchased shall be new and per specifications contained herein.

7.0 Documentation By the Seller

The Seller shall provide all documentation listed below:

- a) Detailed equipment installation procedures
- b) “As Installed Drawings” showing the exact location of all installed equipment. The equipment shall be referenced to building walls and Survey Monuments.
- c) Grout testing reports
- d) Completed Alignment Data Sheets
- e) Piping Test Reports



SPECIFICATION

**WA LIGO SITE (LHO) - CORNER STATION ADV. LIGO
VACUUM EQUIPMENT INSTALLATION**

8.0 Attachments Summary

The following attachments referenced herein are part of this specification and are available via the links in the Statement of work (SOW) - **CXXXXXXXX**:

LIGO Building Equipment Layout/Piping Drawings:

WA Corner Station Layout	-	D1003179
WA Corner Piping Arr. (PSI V049-5-012) Sht. 1	-	D961174
WA Corner Station Piping Section (PSI V049-5-014) Sht. 1	-	D961176

Equipment Outline Drawings:

HAM Layout (PSI V049-4-002)	-	D961094
Existing MC Spool (PSI V049-4-B3A)	-	D961153
New MCA (GNB-114145-00)	-	C1001348
New MCB (GNB-114146-00)	-	C1001349

Specifications

Spec. for Anchor Bolt / Grout Installation	-	E1000712
Spec. for Contamination Control	-	E1000719
Spec. for Component Alignment	-	E1000716
Spec. for O-Ring and Flange Installation	-	E0900431
Piping Cleaning Procedure	-	E1000715
Spec. for Piping Design / Material	-	E1000713
Spec. for Piping Thermal Insulation	-	E1000717
Spec. for Vacuum / Clean Air Piping	-	E1000718